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Keith Arnold, Director

PRESCRIBED BURN FIRECLIMATE SURVEY 1-57

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and

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

The Experiment Station is maintained at Berkeley,
California in cooperation with the University of California.

FOREWORD

Fireclimate Studies—Their Purpose

Experience and research have taught fire fighters a good deal about wildland fire. Its general relationship to weather, fuels, and topography is well known. Application of this knowledge to control of fire is frequently hampered by lack of information about the behavior of fireclimate in specific places—how wind, temperature, humidity, and fuel moisture are affected by topography, water bodies, season, and the fire itself. The existing system of weather stations provides enough information for general weather forecasts but not enough to define local fireclimate patterns. The stations are relatively few, widely spaced, and seldom equipped with recording instruments. They gather only momentary samples of weather conditions and provide no information on the way the fire itself affects the patterns.

To obtain this needed information, the Station has started studies aimed at establishing some of the principles controlling local fireclimate patterns and the effect of fire on these patterns. A four-pronged attack will be made on the problem:

1. Semi-permanent fireclimate surveys wherein distinct topographic types will be intensively instrumented for one or more years primarily for the study of variations in local fireclimate patterns in relation to more general weather patterns.

2. Temporary or mobile surveys that will permit exploratory studies of fireclimate patterns around prescribed burns and wildfires and short-term detailed studies of various phases of broader scale fireclimate patterns.

3. Analysis of existing fire and weather records to establish, if possible, the relation of pattern of past fires to weather patterns.

4. Controlled laboratory studies aimed at determination of the fundamental laws governing fireclimate patterns and effects of fire on these patterns.

ABSTRACT

The Prescribed Burn Fireclimate Survey 1-57 was the first of four prescribed burn surveys in 1957. In this burn we were looking particularly for effects of fire on the wind patterns on the lee side of the fire. Instrumentation, observation techniques, and data collected were such, however, that fireclimate patterns for the burn area could be related to the general weather pattern.

One surprising phenomenon observed in the survey was an increase in wind speed on the lee side of the fire near the head of one small canyon. This is an area where indrafts have usually been thought to decrease prevailing wind speed or to change its direction. This apparent effect of fire must have further investigation and study.

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THE SURVEY AREA

The prescribed burn was conducted on the San Joaquin Experimental Range and the Shaubach ranch property, in the lower foothills of the west slope of the Sierra Nevada, about 24 miles northeast of Fresno, California. The area of about 400 acres varies in elevation from 900 to 1, 500 feet. Slopes are generally moderate over most of the area but become steep in the upper elevation of the two drainages that traverse the area. The whole burn area had a westerly aspect.

Ground cover was typical of the Sierra foothills in this area. It consisted principally of a light stand of dry annual grasses, scattered clumps of brush (dense in spots) 2 to 4 feet tall, an open stand of oak trees, and numerous mature digger pines (fig. 1). The digger pines had been felled during the winter and spring and provided the chief heavy fuel.

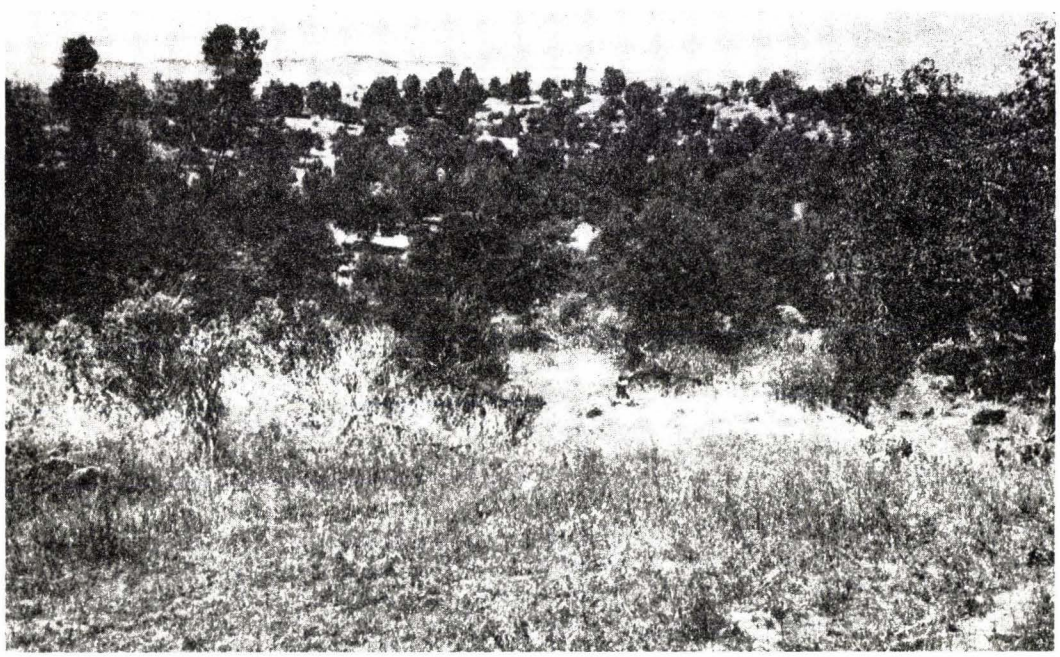

Figure 1. --Typical fuel conditions on the San Joaquin Range prescribed burn.

SURVEY PROCEDURE

To make the most effective use of available instruments and manpower, we concentrated our efforts chiefly on the eastern edge of the area where the hottest fire activity was most likely because of the steeper slopes, more dense fuels, and probable west or southwest wind.

Five sites were selected for the recording instruments (fig. 2). Station A was located in a saddle just above a small but well defined ravine. Station B was located on a rounded, well exposed ridge about 100 feet higher than Station A. The location of Station C was similar to Station B but about 50 feet lower. Station D was at the center of a small dam in the southeast drainage. Station E was on a well exposed ridge far enough from the burn area, we estimated, to be free of most fire effects. Wind speed and direction were recorded continuously at these stations. At Station E temperature and humidity were also recorded by means of a hygrothermograph.

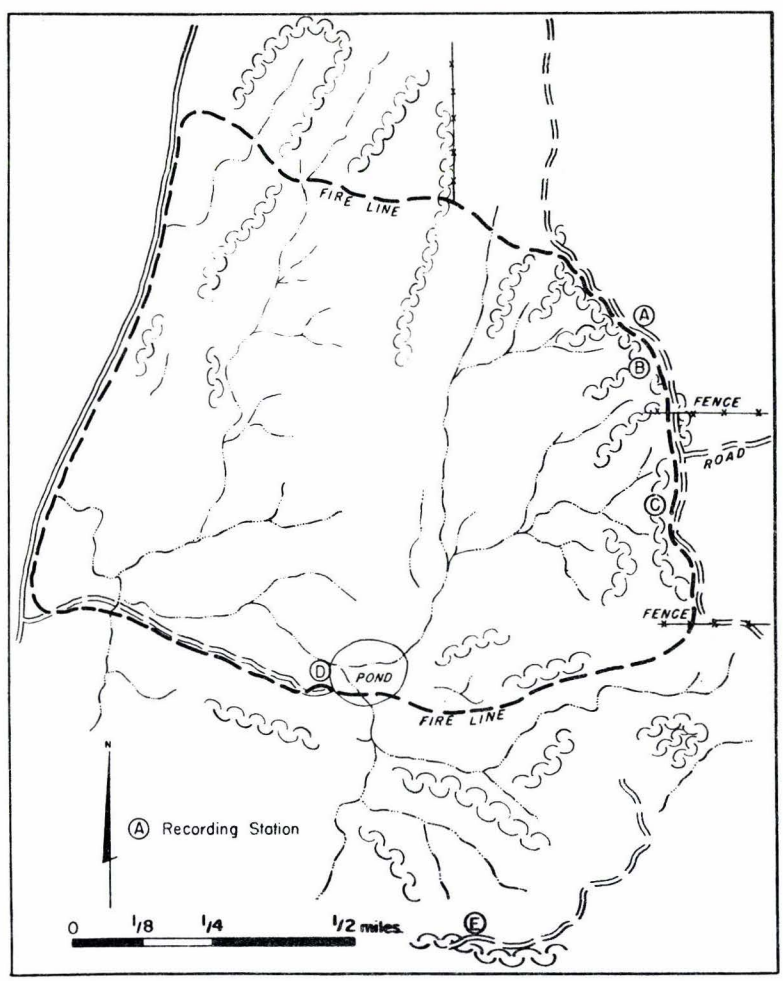

Figure 2.--Prescribed Burn 1-57, July 13, 1957.

We also established 18 other stations where wind speed and direction were measured intermittently with manually operated instruments. Temperature and humidity readings were made at these and the recording stations with sling psychrometers. The stations for manual observations were selected so as to give as complete a picture as possible of conditions within the burn area, and hence were located on minor ridges, in ravines, and on slopes.

Observations were started on July 10, three days ahead of the prescribed burn, scheduled for ignition at about noon on July 13.

GENERAL WEATHER

The general weather pattern during the period of the survey was typical for July. At the surface, the usual thermal low could be found in the vicinity of the California-Arizona border, and a low pressure trough up the Central Valley of California persisted until after the day of the burn.

A low pressure area moved eastward across the eastern Pacific and then curved northeastward into Washington July 10. However, the attendant cold front dissipated as it moved through central California July 11 and did not significantly affect the thermal trough or the high temperatures. The weather remained slightly warmer than normal through July 12.

A second low pressure system moving eastward across the eastern Pacific stagnated and filled off the coast of Washington July 13 and 14. Its attendant cold front, however, was stronger than the first and was associated with an upper-air trough. Some cooling took place in central California July 13 in advance of the cold front, and the frontal passage July 14 brought more cooling and temporarily destroyed the thermal trough extension up the Central Valley. Temperatures dropped to slightly below normal.

Aloft at the 700 millibar level (about 10,000 feet), winds were light and variable over central California at the beginning of the survey (July 9) but then increased in speed from the southwest and south as a trough developed off the coast. With the passage of the trough July 14, the wind shifted into the west. At the 850 millibar level (about 5,000 feet), the temperature over Oakland decreased about 16° F. from July 12 to 14 with the passage of the upper-air trough.

From the Oakland radiosonde observations and the maximum temperatures at Fresno, it is estimated that heating was sufficient each day to produce a dry-adiabatic lapse rate up to about 5,000 feet mean sea level.

RESULTS

Local Fireclimate Patterns

The general weather pattern existing at the time of this survey showed that we could expect winds from a northerly direction most of the nighttime hours. Average wind speeds during these hours decreased from 6 to 10 miles per hour during the early evening, to 2 to 4 miles per hour, and frequent calm periods, shortly before sunrise.

After sunrise the wind came from the east and southeast and then veered to south or southwest sometime between 1100 and 1300. As the day progressed, the wind direction continued to shift clockwise and by the middle of the afternoon, came from the west. The wind then continued to veer around to northwest and again to north and northeast after sundown.

Wind speeds increased during the day from 2 to 3 miles per hour over the ridges at about sunrise to 8 or 10 miles per hour with gusts to 20 miles per hour in the middle and late afternoon. On the spur ridges wind speeds were about the same as on the main ridges when the wind was from the southeast, south, southwest, or west. At these times, wind speeds in the ravines and gullies were one-half to one-third the ridgetop speeds. North and northwest winds gave wind speeds on main ridges nearly double that on the spur ridges. At the same time, there was little or no wind in the ravines and gullies.

Maps of "normal" wind direction and speeds were prepared for the expected fire period for the use of the fire boss (fig. 3, 4, 5, and 6). A special fire-weather forecast for the prescribed burn on July 13 was also prepared in cooperation with the U. S. Weather Bureau:

> Few high clouds, otherwise fair. Unstable air to 5,000 feet due to surface convection. Stable air above 5,000 feet. Dewpoint at 5,000 feet 28° F. Upslope wind 5-12 miles per hour expected during afternoon. Probable temperature and humidities:
>
> | Time | Temperature | Humidity |
> |---|---|---|
> | 1100 | 93 | 25% |
> | 1400 | 101 | 16% |
>
> General conditions about the same as July 12.

Actual conditions on the burn area followed reasonably close to the forecast conditions. At Station E at 1100, the temperature was 84° and the relative humidity was 22 percent. At 1400 the temperature was 94° and the humidity 13 percent. At this station, winds were upslope as forecast and averaged 6 to 10 miles per hour.

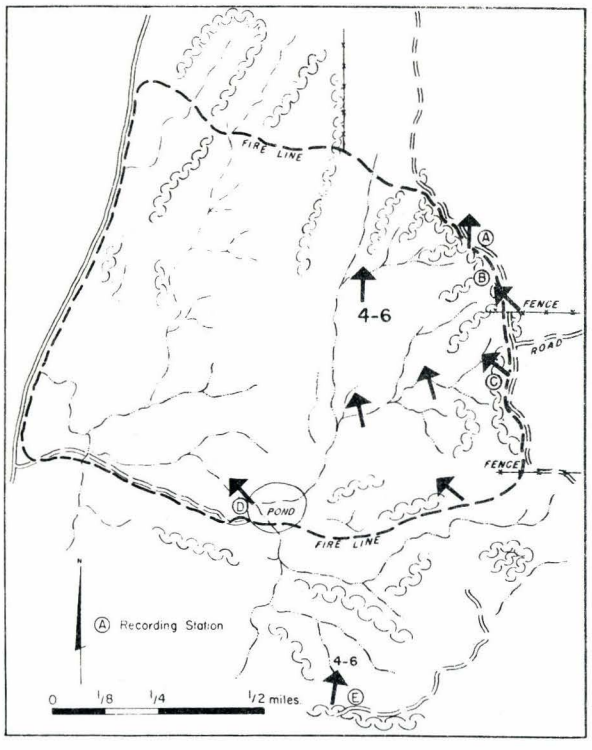

Figure 3. --Expected wind pattern at 1100 hours PST on the San Joaquin Range Prescribed Burn.

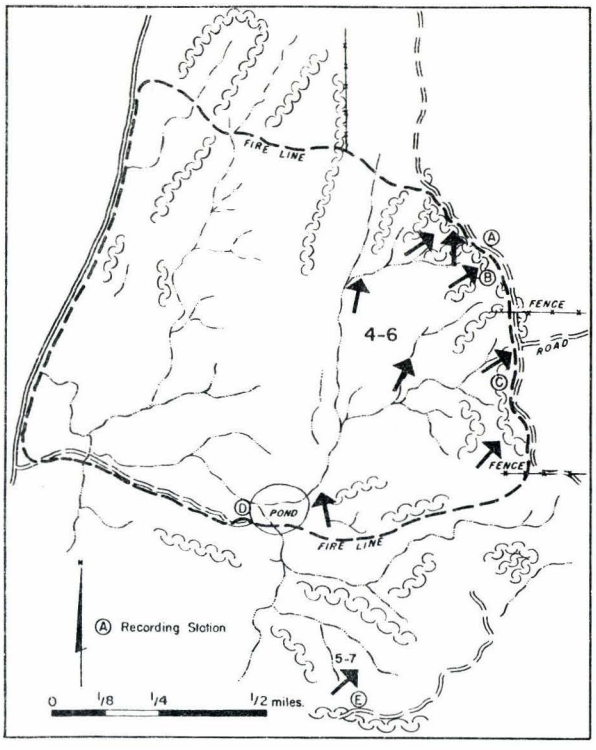

Figure 4. --Expected wind pattern at 1200 hours PST on the San Joaquin Range Prescribed Burn.

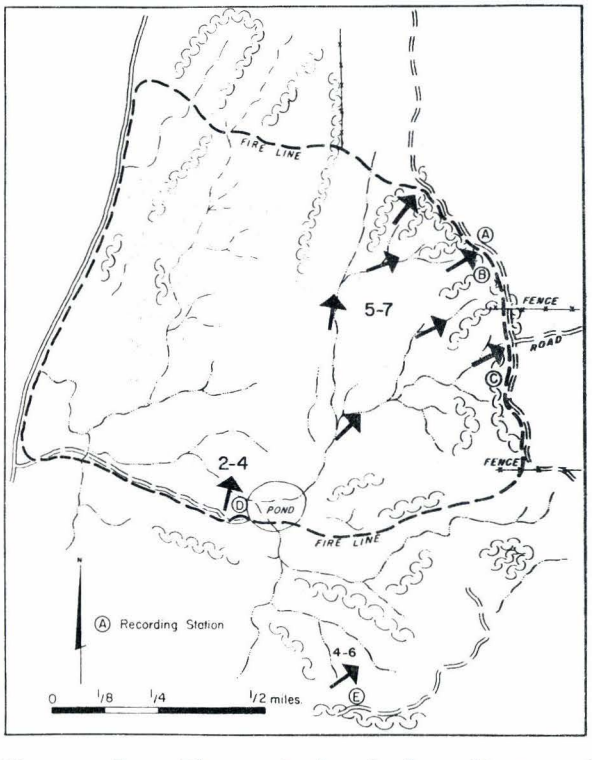

Figure 5. --Expected wind pattern at 1300 hours PST on the San Joaquin Range Prescribed Burn.

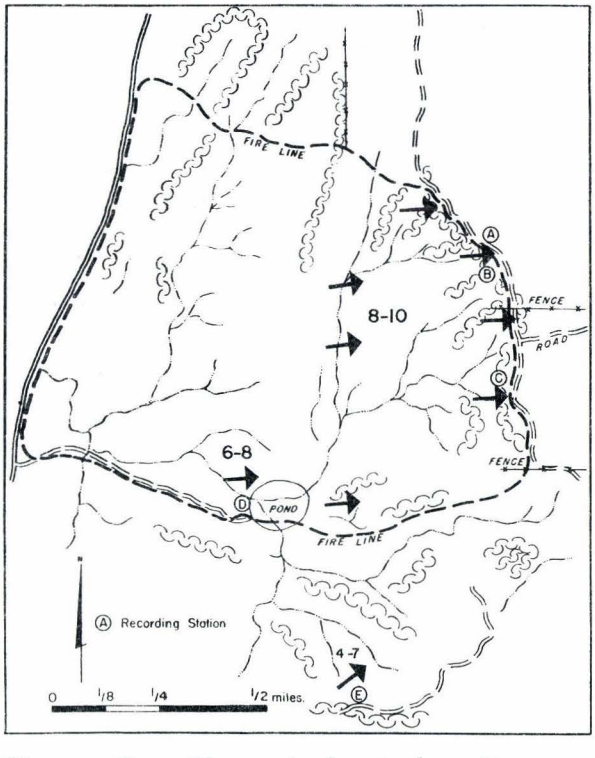

Figure 6. --Expected wind pattern at 1500 hours PST on the San Joaquin Range Prescribed Burn.

Effects of Fire

Firing on the burn started at 1130 PST in the vicinity of point F (fig. 2) and proceeded in both directions around the perimeter from that point. The firing plan called for the firing to be completed on the north, east, and part of the west sides of the fire before fire was brought along the southern edge. Firing proceeded very slowly along the north and east lines, and further delay occurred on the southeast corner where some difficulty was experienced in holding the fire. As a result, the fire backed downhill slowly from stations A, B, and C and was a considerable distance from the fireline before the south line was fired and any sustained run toward the weather stations was possible. Because much of the more dense standing fuel was burned in a backing down fire and because the heavy fuel was concentrated in scattered spots, the fire tended to develop local "hot spots" (fig. 7) rather than a hot moving front. Only for a few minutes during one short run did a very active convection column develop (fig. 8).

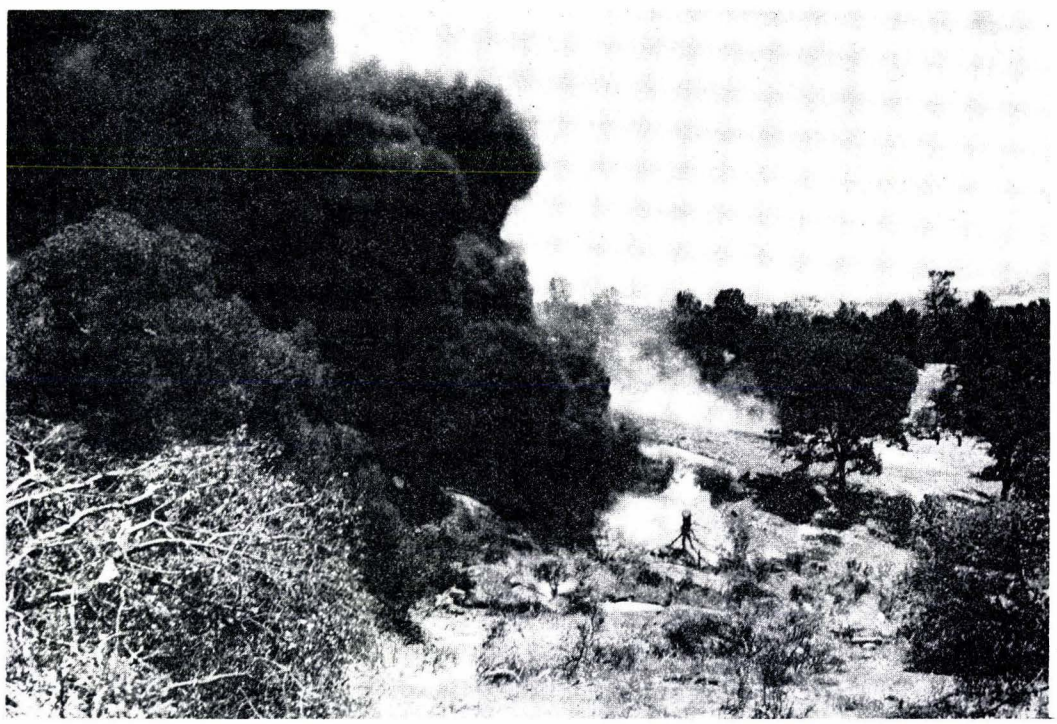

Figure 7. --The fire tended to develop local "hot spots".

Figure 8. --A strong convection column developed only for a few minutes. Here the top of the column has reached the condensation level.

Although a hot moving front did not pass the observation stations as we had hoped, the fire did appear to affect the wind patterns significantly. As the fire was brought along the line near Stations A and B and heat built up along the northeast line, the wind direction—first at Station A and then Station B—switched from the prevailing southwest direction, clockwise toward the north (fig. 9). This effect was more pronounced at Station A than at Station B, which seemed often to be above the limit of heat activity. Station E showed little variation from the prevailing direction (fig. 9). The tendency for the wind to blow from more northerly directions persisted at Station A throughout the fire. At times the wind became very variable in direction. This change in direction apparently was confined to the lower levels since smoke movement at the top of the convection column and outside the fire area was toward the east and northeast: with the prevailing wind.

Observers' notes on position and activity of the fire near Station A and the detailed wind record revealed another important apparent fire effect. The perimeter firing first brought fire into the vicinity of Station A about 1148 PST. As the fire built up heat in the heavy fuels near the fireline in the saddle and ravine at Station A, the wind shifted from southwest to west (directly up-canyon) and picked up in speed (fig. 10). Station B, which was not yet involved in the fire, showed no change in wind direction nor material change in speed (fig. 10). As the heavy fuel near the fireline was consumed and the fire carried on toward Stations B and C, the wind again shifted from southwest toward the north.

About 1210 PST, the fire below Station A had backed down slope into another heavy fuel concentration. When this burned, the wind once again changed to the up-canyon westerly direction and the speed showed a sharp increase (fig. 11). Station E, outside the fire area, showed little change in speed or direction at this time.

During the time the fire was burning briskly on the slope below Station B, the wind direction also switched to the west, blowing directly up slope out of the fire toward the station (fig. 12). The increase in wind speed observed in the topographically confined area at Station A did not occur at Station B, which was well exposed on an open ridge.

A wind blowing out of the fire at increased speed is contrary to the wind action commonly believed to occur. Most observers have believed that indrafts into the fire area usually reduce wind speed and frequently reverse the direction of the prevailing wind on the lee side of a fire. Most of such effects, however, have been observed at some distance from the fire edge so that little quantitative information is available about wind action as close to the fire as these survey observations. Although natural variations in wind speed and direction could account for the wind action observed, the coincidence of increased fire activity with changes in wind would indicate the effect was real.

In the topographically confined area below Station A, the heated air moving up-canyon from the fire may have created a very local low pressure around and ahead of the fire front. Movement of air into the fire from its sides and head would be restricted by the topography and moving warm air. The effect would then be to accentuate the normal up-canyon wind. The inertia of the air moving up-canyon could carry it well ahead of the fire front and produce the increase in wind speed that was observed. In a less confined area such as at Station B, the movement of heated air and also surrounding air would be much less restricted and the effect of a localized low pressure zone on wind speed would be less pronounced.

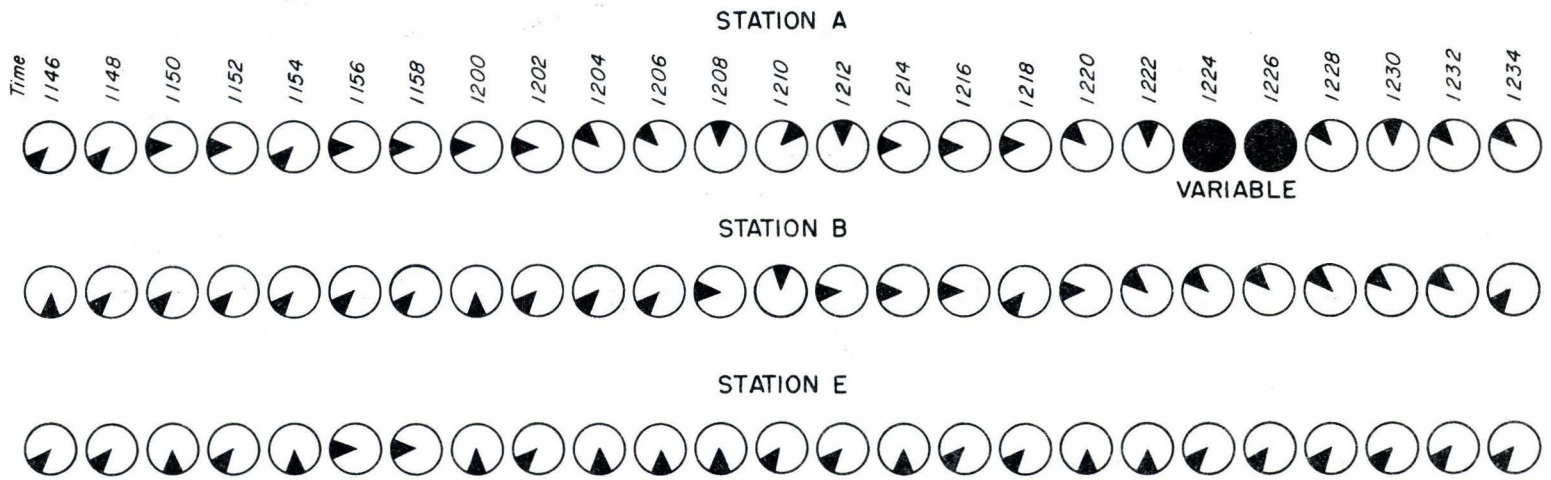

Figure 9. --Wind directions at Stations A, B, and E, 1146 to 1234 hours.

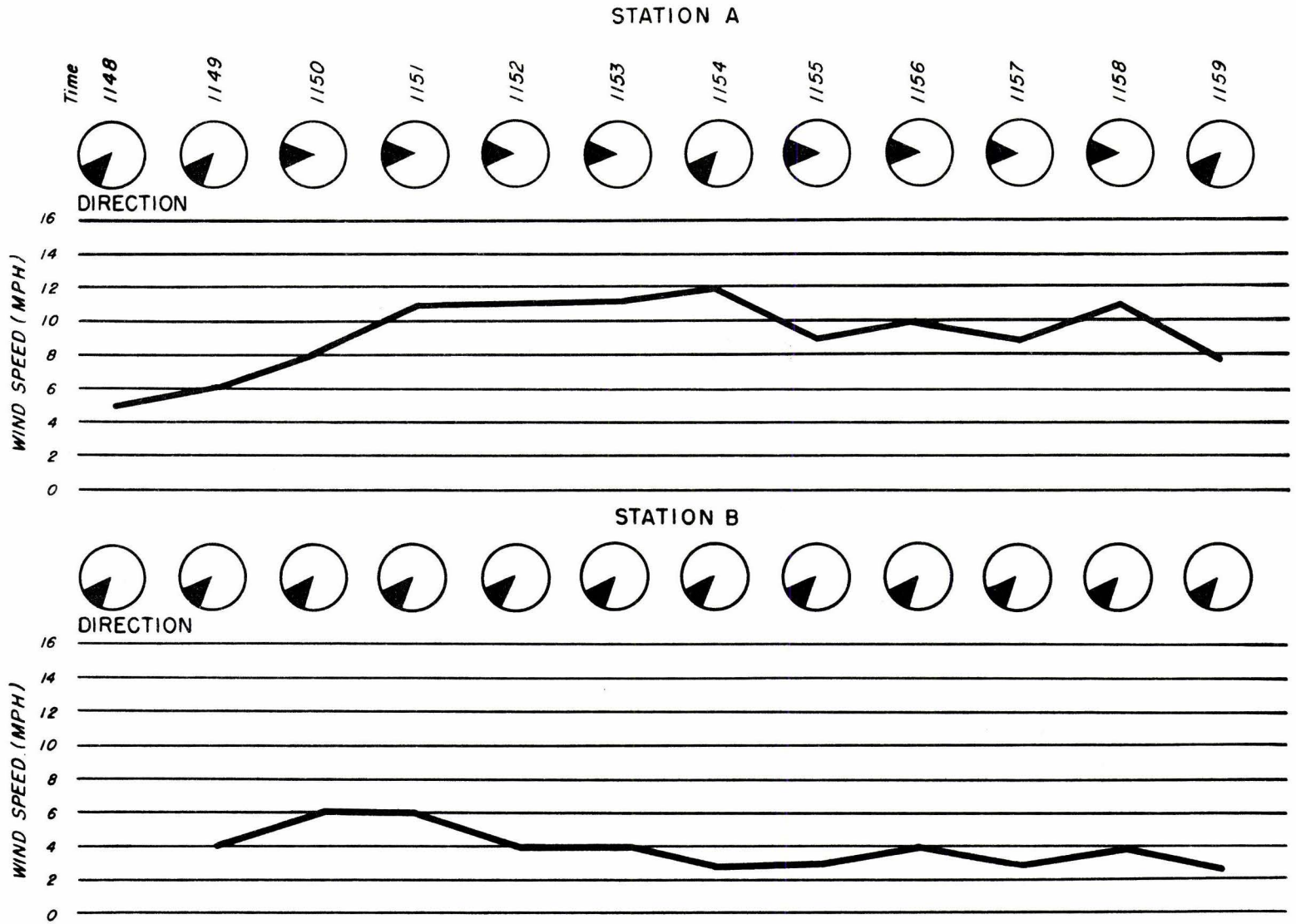

Figure 10. --Wind directions and speed 1148 to 1159 hours at Stations A and B.

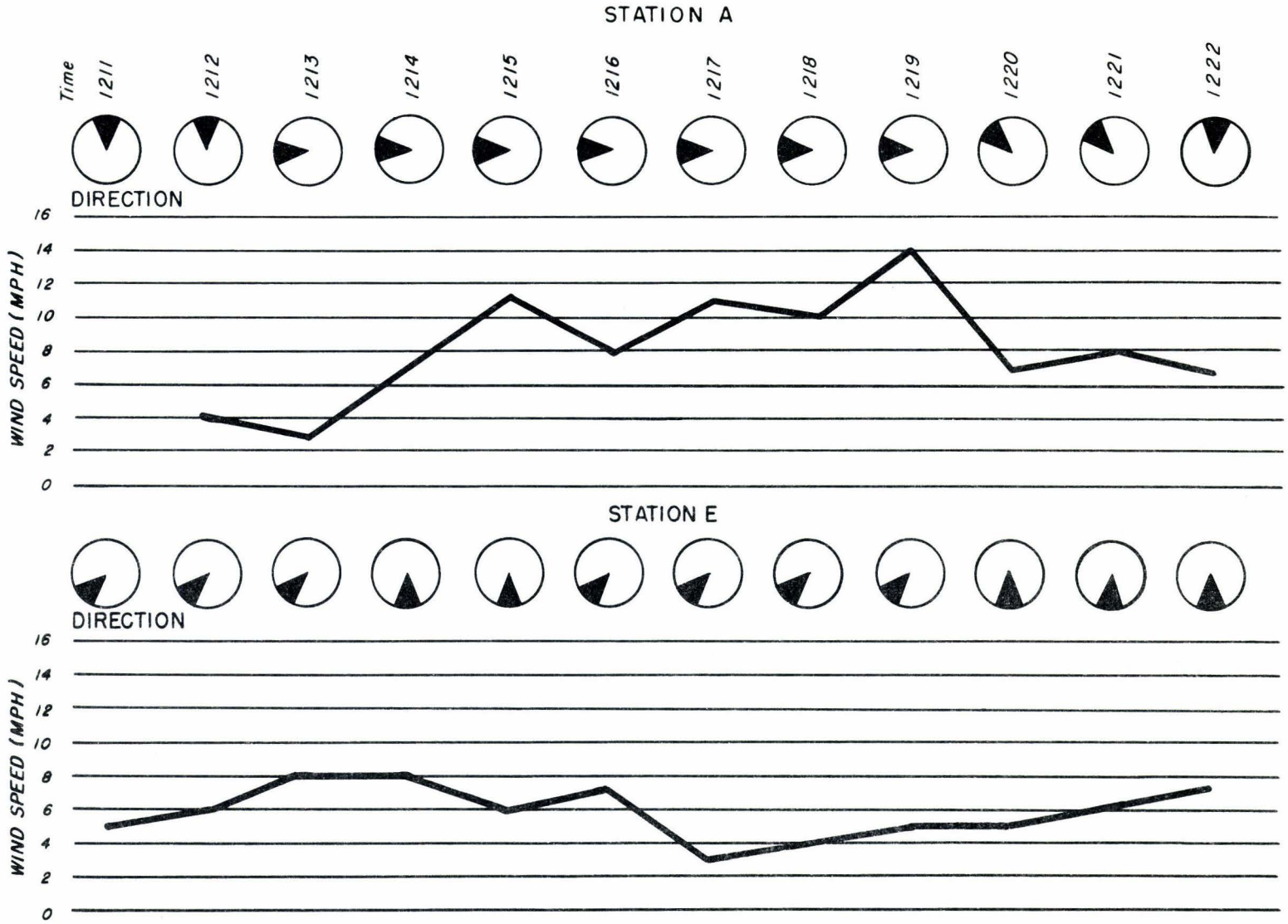

Figure 11. --Wind direction and speed at Stations A and E, 1211 to 1222 hours.

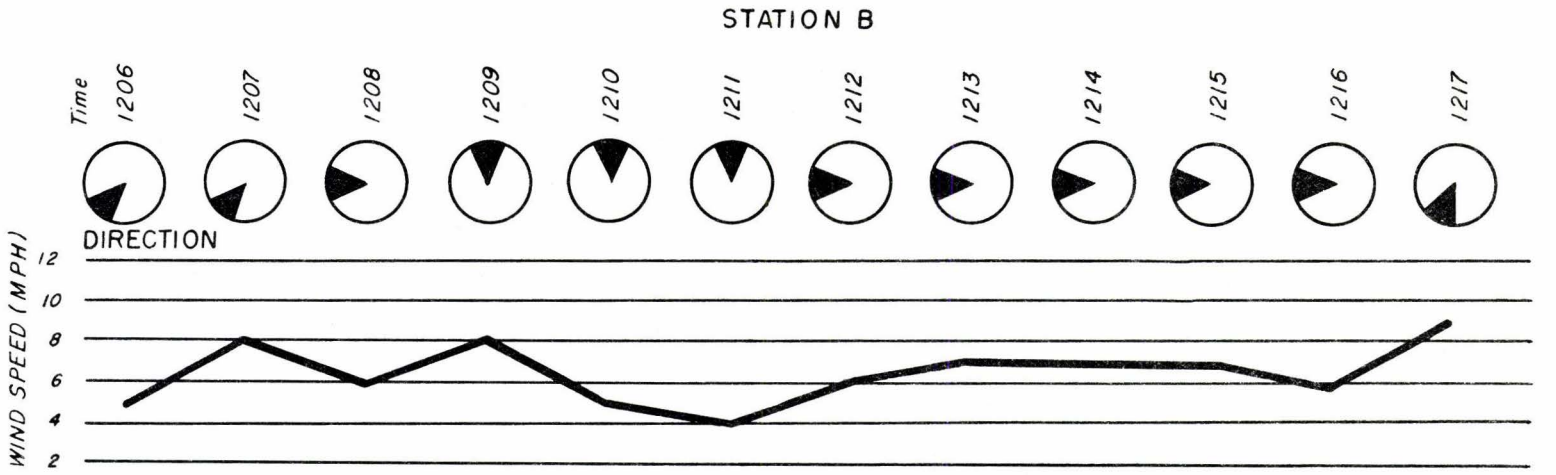

Figure 12. --Wind speed and direction at Station B, 1206 to 1217 hours.

Some measure of the degree of heating of air ahead of a fire is shown by a series of observations made at Station C. Here we were attempting to measure the effect of smoke on the amount of water vapor in the air by means of wet and dry bulb thermometer readings. Smoke density was never very great, and we could not detect any significant change in the amount of water vapor in the air. Increases in air temperature, however, were noted when the air movement was across the burning area. For example, at 1200 the temperature at Station C was 88° F., about the same as at Station E at a distance from the fire (table 1). At 1230 the temperature at Station C jumped to 98° when the fire was brought along the slope below the station and remained above "normal" for more than 15 minutes. Again at 1335 and 1410 when the wind shifted so as to blow across the burn area, increases in temperature were evident. These abrupt changes in temperature were not noted at Station E where there was the usual afternoon trend in temperature.

Table 1. --Effect of fire on air temperatures

Time	Temperature	
	Station C	Station E
1130	86	
1150		89
1200	88	
1225		90
1230	98	
1245	96	
1250	92	
1252		90
1255	92	
1305	91	
1310	94	
1316		93
1320	91	
1335	96	
1336		94
1340	93	
1350	94	
1353		94
1355	89	
1410	95	
1416		94
1420	92	

CONCLUSIONS

The San Joaquin Range prescribed burn again demonstrated the feasibility of quickly determining local wind patterns when the general weather conditions are stable, as did a previous survey. 1/ The behavior pattern of the fire was that which could be expected from the wind pattern, fuel distribution, and method used in firing the area.

The apparent anomaly of the wind speed increasing ahead of the fire, opens up a wide field of speculation and points up a need for further investigation of wind movement close to an active fire. If commonplace, this phenomenon may be a clue to the mechanism by which fire spreads up canyon against a strong wind. It may also help to explain the "blowtorch" effect often observed at the head of a ravine or gully. More observations are needed in order to substantiate the increase in wind as a real fire effect and not an ephemeral event. If real, then we must know under what conditions of topography, fuels, winds, and other fire environment factors the effect can occur.

This study also brings more sharply into focus the need for laboratory studies in this field. On-the-ground surveys and studies are essential for pointing out and defining the limits of problems needing more research, such as the increase in wind ahead of the fire. It is only through laboratory studies, however, where conditions can be controlled and duplicated, that we can hope to discover the basic laws creating and controlling such a phenomenon.

1/ Fireweather Survey Can Aid Prescribed Burning, Schroeder, M. J., and Countryman, C. M., Calif. Forest and Range Expt. Sta., Tech. Paper No. 21, November 1957, 10 pp., illus.